Science 10
Course Outcomes
Second (validation) Draft

May 1999

Revisions to this second (validation) draft will be made on the basis of classroom field testing and other advice received. Reviewers are encouraged to submit suggestions for improving the clarity of learning outcomes and examples. A resource development draft, incorporating revisions, is scheduled to be made available in November 1999.

Unit Organization

In Grades 7–9, five units of study are outlined at each grade level. At grades 10–12, four units of study are outlined for each grade level. Each unit includes the following components.

Unit Overview

Each unit of study begins with an overview that introduces the contents of the unit and suggests an approach to its development.

Focussing Questions

These questions frame a context for introducing the unit and suggest a focus for investigative activities and application of ideas by students.

Key Concepts

Key concepts identify major ideas to be developed in each unit. Some of the key concepts may be addressed in additional units at the same grade/course level, as well as at other grade/course levels. The intended scope of treatment of these concepts is indicated by the learner outcomes.

Outcomes

Two levels of outcomes are provided in the draft program and courses of study:

- General Outcomes: These are the major outcomes for each unit. For STS and knowledge, the outcomes are combined and unique to each unit. For skills and attitudes, the outcomes are common to all units.
- Specific Outcomes: These are detailed outcomes that flesh out the scope of each unit. They are shown in bulleted form.

Examples

Many of the outcomes are supported by examples. The examples **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed. Illustrative examples are written in *italics* and separated from the outcomes by being placed in parentheses.

Unit Emphases

Each unit of study in secondary science begins with an overview and a set of focussing questions that identify a context for study. In defining the context, one of the following areas of emphasis is identified for each unit.

- *Nature of Science* emphasis: In these units student attention is focused on the processes by which scientific knowledge is developed and tested, and on the nature of the scientific knowledge itself. Skills emphasized in these units are the skills of scientific inquiry.
- *Science and Technology* emphasis: In these units students seek solutions to practical problems by developing and testing prototypes, products and techniques to meet a given need. The skills emphasized are those of problem solving, in combination with the skills of scientific inquiry.
- *Social and Environmental Contexts* emphasis: In these units student attention is focused on issues and decisions relating to how science and technology are applied. Skill emphasis is on the use of research and inquiry skills to inform decisions; students seek and analyze information and consider a variety of perspectives.

Unit A: Energy and Matter in Chemical Change *(Nature of Science emphasis)*

Overview: Chemical changes involve energy and matter transformations. A knowledge of the underlying structure of matter and the basic chemical species is important in understanding chemical change. Simple models of ions and molecules are useful in providing operational explanations of how elements combine to form compounds, and why chemical changes occur. As students explore the properties of molecular and ionic compounds, including acids and bases, they begin to appreciate the need for a classification scheme and a system of nomenclature. Students expand their knowledge of chemistry from Science 9 to name compounds, classify, and write balanced chemical equations to represent chemical changes occurring in living and nonliving systems. The law of conservation of mass, the basis of the mole concept, is introduced to students, providing a means to predict amounts of reactants and products.

Focussing Questions: How has technology furthered our understanding of the basic particles of matter, and how has knowledge of the structure of matter led to other scientific advancements? How do elements combine, and can these combinations be classified and the products be predicted and quantified? Why do scientists classify chemical change, follow guidelines for nomenclature and represent chemical change by equations?

Key Concepts

The following concepts are developed in this unit and may also be addressed in other units at other grade levels. The intended level and scope of treatment is defined by the learning outcomes below.

- ☆ ancient understandings and applications of the properties of materials
- ☆ WHMIS and safety concerns
- ☆ naming compounds using the International Union of Pure and Applied Chemistry (IUPAC) guidelines, ionic and molecular compounds, acids and bases
- ☆ relationship of structure to chemical properties
- ☆ role and need for classification (nomenclature systems, periodic table)
- ☆ significance of chemical change in living and nonliving systems
- ☆ health and environmental concerns related to chemical elements, compounds and reactions
- ☆ writing and balancing equations
- ☆ law of conservation of mass and the mole concept

STS and Knowledge Outcomes

Students will:

1. Describe the basic particles that make up the underlying structure of matter, and investigate related technologies
   - provide examples of how early humans worked with chemical substances to meet their basic needs *(e.g., the use of dyes and smelting of ores by North American aboriginals)*
   - outline the role of evidence in the development of the atomic model; i.e., Dalton, Thomson, Rutherford, Bohr
   - describe isotopes and illustrate with examples how they are used in technological devices *(e.g., medical devices, carbon 14 dating and heavy water)*
   - outline the debate regarding the merits of using public funds to investigate subatomic particles *(e.g., the money, approximately $100 000 000 US, spent on discovering the internal structure of the proton and the existence of quarks)*
   - provide examples of chemistry-based careers in their community *(e.g., chemical engineers, cosmetology, food processing)*

2. Explain, using the periodic table, how elements combine to form compounds, and follow IUPAC guidelines for naming ionic compounds and simple binary molecular compounds
   - illustrate an awareness of WHMIS guidelines, and demonstrate safe practices in handling, storing and disposing of chemicals in the laboratory and at home
   - explain the importance of and the need for the IUPAC system of naming compounds, in terms of the work that scientists do and the need to communicate clearly and precisely
   - demonstrate an understanding of the periodic table, by predicting properties of elements based on the properties of adjacent elements
   - explain, using the periodic table, how and why elements combine to form compounds in specific ratios
   - predict formulas and write names for ionic and molecular compounds and acids, using a periodic table, a table of ions and IUPAC rules
   - classify, on the basis of properties—i.e., conductivity, pH, solubility, state—names and formulas, ionic and molecular compounds, including acids and bases
   - predict whether an ionic compound is fully soluble in water, by consulting a solubility chart
   - relate the molecular structure of simple substances to their properties *(e.g., describe how the properties of water are due to the polar nature of the water molecule, and relate these properties to the transfer of energy in physical and living systems)*
   - outline the issues related to personal and societal use of potentially toxic or hazardous compounds *(e.g., health hazards due to excessive consumption of alcohol and nicotine; exposure to toxic substances; environmental concerns related to the handling, storage and disposal of heavy metals, strong acids, flammable gases, volatile liquids)*

3. Identify and classify chemical changes, and write word and balanced chemical equations for significant chemical reactions, as applications of the law of conservation of mass
   - provide examples of household, commercial and industrial processes that use chemical reactions to produce useful substances and energy *(e.g., baking powder in baking, combustion of fuels, electrolysis of brine into $Cl_{2(g)}$ and caustic $NaOH_{(aq)}$)*
   - identify chemical reactions that are significant in our society *(e.g., reactions that maintain living systems, such as photosynthesis and respiration; reactions that have an impact on the environment, such as combustion reactions)*
   - describe the evidence for chemical changes; i.e., energy change, formation of a gas or precipitate, colour or odour change, change in temperature
   - explain the role of energy in chemical change, and differentiate between endothermic and exothermic chemical reactions *(e.g., separation of metals from ores, protection of metals from corrosion, dissolving of salts, combustion of gasoline, photosynthesis)*
   - classify and identify categories of chemical reactions; i.e., formation, decomposition, hydrocarbon combustion, single replacement, double replacement
   - write word and balanced chemical equations for chemical reactions that occur in living and nonliving systems
   - predict the products of simple composition and decomposition chemical reactions, given the reactants; and predict the reactants, given the products **[Prerequisite Skills: Grade 8 Mathematics, Strand: Number, SOs 12 and 15]**
   - define the mole as the amount of an element containing 6.02×10^{23} atoms, and extend the concept to amounts of substances made of other chemical species (*e.g., the amount of water that contains 6.02×10^{23} molecules of H_2O*) **[Prerequisite Skills: Grade 7 Mathematics, Strand: Number, SO 3 and Grade 8 Mathematics, Strand: Number, SO 15]**

- interpret balanced chemical equations in terms of moles of chemical species, and relate the mole concept to the law of conservation of mass **[Prerequisite Skills: Grade 8 Mathematics, Strand: Number, SOs 12 and 15]**

Skill Outcomes *(focus on scientific inquiry)*

Initiating and Planning

Students will:

Ask questions about observed relationships, and plan investigations of questions, ideas, problems and issues

- identify questions that arise from practical problems and issues *(e.g., what is the best material to use for a particular product or need)*
- design an experiment, identifying and controlling major variables *(e.g., design an experiment to differentiate between categories of matter, such as acids and bases)*
- state a prediction and hypothesis based on available evidence and background information *(e.g., hypothesize as to what happens to baking soda during baking)*
- evaluate and select appropriate instruments for collecting evidence and appropriate processes for problem solving, inquiring and decision making *(e.g., list appropriate instruments and apparatus that may be required to test the law of conservation of mass involving chemical species in the solid, aqueous, or gaseous phases)*

Performing and Recording

Students will:

Conduct investigations into relationships between and among observable variables, and use a broad range of tools and techniques to gather and record data and information

- carry out procedures, controlling the major variables and adapting or extending procedures where required *(e.g., when performing an experiment to illustrate conservation of mass, demonstrate an understanding of closed and open systems and control for loss or gain of matter during a chemical change)*
- use library and electronic research tools to collect information on a given topic *(e.g., compile information on compounds we use and their toxicity, using standard references such as the Merck Index, as well as Internet searches)*
- select and integrate information from various print and electronic sources or from several parts of the same source *(e.g., collect information on the latest technologies based on the use of electrons, protons and neutrons, research into subatomic matter, such as neutrinos)*
- demonstrate a knowledge of WHMIS standards, by selecting and applying proper techniques for handling and disposing of laboratory materials *(e.g., recognize and use MSDS information)*
- select and use apparatus and materials safely *(e.g., use equipment, such as Bunsen burners, electronic balances and laboratory glassware, correctly and safely)*

Analyzing and Interpreting

Students will:

Analyze data and apply mathematical and conceptual models to develop and assess possible solutions

- describe and apply classification systems and nomenclature used in the sciences *(e.g., classify matter, and name elements and compounds based on IUPAC guidelines)*
- apply and assess alternative theoretical models for interpreting knowledge in a given field *(e.g., compare models for the structure of the atom)*

- compare theoretical and empirical values and account for discrepancies *(e.g., measure the mass of a chemical reaction system before and after a change, and account for any discrepancies)*
- identify and apply criteria; i.e., social factors, explanations, methods, data, related research and relevance, including the presence of bias, for evaluating evidence and sources of information *(e.g., evaluate the environmental or health impact of a chemical)*
- identify and explain sources of error and uncertainty in measurement, and express results in a form that acknowledges the degree of uncertainty *(e.g., measure and record the mass of a material)*
- identify new questions or problems that arise from what was learned *(e.g., how did ancient peoples find out how to separate metals from their ores?)*

Communication and Teamwork

Students will:

Work as members of a team in addressing problems, and apply the skills and conventions of science in communicating information and ideas and in assessing results

- communicate questions, ideas and intentions; and receive, interpret, understand, support and respond to the ideas of others *(e.g., use appropriate communication technology to elicit feedback from others)*
- select and use appropriate numeric, symbolic, graphical and linguistic modes of representation to communicate ideas, plans and results *(e.g., use appropriate SI notation, IUPAC nomenclature)*

Attitude Outcomes

Appreciation of Science

Students will be encouraged to:

- value the role and contribution of science and technology in our understanding of phenomena that are directly observable and those that are not *(e.g., recognize the usefulness of being skilled at mathematics and problem solving; appreciate how scientific problem solving and the development of new technologies are related)*
- value the contributions to scientific and technological development made by men and women from many societies and cultural backgrounds *(e.g., recognize the research of both men and women in science)*

Interest in Science

Students will be encouraged to:

- consider further studies and careers in science- and technology-related fields *(e.g., recognize that part-time jobs require science- and technology-related knowledge and skills)*

Scientific Attitudes

Students will be encouraged to:

- use factual information and rational explanations when analyzing and evaluating *(e.g., critically evaluate inferences and conclusions)*
- value the processes for drawing conclusions *(e.g., critically assess their opinion of the value of science and its applications)*

Collaboration

Students will be encouraged to:

- work collaboratively in planning and carrying out investigations, as well as in generating and evaluating ideas *(e.g., willingly work with any classmate or group of individuals, regardless of their age, gender, or physical and cultural characteristics; assume a variety of roles within a group, as required; accept responsibility for any task that helps the group complete an activity)*

Safety

Students will be encouraged to:

- show concern for safety, and accept the need for rules and regulations *(e.g., safely handle and dispose of chemicals; use equipment, such as hot plates and laboratory glassware, correctly and safely)*
- be aware of the direct and indirect consequences of their actions *(e.g., acknowledge the need for safe methods for handling and disposing of potentially hazardous materials in the home and laboratory)*

Unit B: Energy Flow in Technological Systems *(Science and Technology emphasis)*

Overview: The first and second laws of thermodynamics have been useful in the development of modern and efficient energy conversion devices. Students investigating mechanical energy conversions and transfers in systems will recognize that while energy is conserved, useful energy diminishes with each conversion. As well, students will understand that energy can only be observed when transferred, and also that mechanical energy can be quantified. The first and second law of thermodynamics, introduced in Science 9, are applied by students to explain energy conversions in natural and technological systems, and as a means to investigate the design and function of domestic and industrial energy conversion technologies.

Focussing Questions: Which came first: science or technology,and is it possible for technological development to take place without help from "pure" science? How did efforts to improve the efficiency of heat engines result in the formulation of the first and second law of thermodynamics? Why are efficiency and sustainability important considerations in designing energy conversion technologies?

Key Concepts

The following concepts are developed in this unit and may also be addressed in other units at other grade levels. The intended level and scope of treatment is defined by the learning outcomes below.

- ☆ technological innovations of engines leading to the development of the concept of energy
- ☆ forms and interconversions of mechanical energy, and "useful" energy
- ☆ definition of kinetic and potential energy and work done
- ☆ one-dimensional scalar motion
- ☆ scalar mechanical energy conversions and relationships (kinetic energy, potential energy and work done)
- ☆ design and function of technological systems and devices involving potential and kinetic energy, and thermal energy conversions
- ☆ efficient use of energy, and environmental impact of inefficient use of energy

STS and Knowledge Outcomes

Students will:

1. Analyze and illustrate how technologies based on thermodynamic principles were developed before the laws of thermodynamics were formulated
   - relate the processes of trial and error leading to the invention of the engine and the subsequent development of the principles of thermodynamics from attempts to improve efficiency *(e.g., the role of James Watt, valve design in automobile engines)*
   - relate the development of power sources, in particular effective engines, to the industrial revolution and to present day first world economics
   - illustrate, by use of examples from natural and technological systems, that energy exists in a variety of forms *(e.g., mechanical, chemical, thermal, nuclear, solar)*
   - analyze and illustrate how the concept of energy developed from observation of heat and mechanical devices *(e.g., the investigations of Rumford and Joule)*
   - describe, qualitatively, current technologies used to transform energy from one form to another, and that energy transfer technologies produce measurable changes in motion, shape or temperature *(e.g., hydroelectric and coal-burning generators, solar heating panels, windmills, fuel cells)*

2. Explain and apply concepts used in theoretical and practical measures of energy in mechanical systems
   - describe the evidence for energy as an observable change, including physical and chemical, and changes to motion, shape and temperature
   - define kinetic energy as change in energy due to motion, and define potential energy as energy due to relative position or condition
   - recognize that (potential) energy is "useful" only when it can be converted from one form to another *(e.g., potential energy to kinetic energy, chemical energy to thermal or electrical energy, electrical energy to thermal energy)*
   - describe acceleration qualitatively *(e.g., change of speed over an interval of time; speeding up, slowing down)*
   - define gravitational potential energy as the work done on lifting a mass against gravity
   - recognize chemical energy as a form of potential energy *(e.g., glucose, ATP, gasoline from Unit A)*
   - define energy as the property of a system that is a measure of its capacity for doing work, and define work done as transfer of energy by mechanical means
   - quantify gravitational potential energy, using $E_p = F_g h$, kinetic energy, using $KE = 1/2mv^2$, work done, using $W = Fd$, and speed, using $v = d/t$ **[Prerequisite Skills: Grade 8 Mathematics, Strand: Patterns and Relations, SOs 4 to 6]**
   - relate changes in kinetic and potential energy and work done
   - derive the SI unit of energy and work, the Joule, from fundamental units **[Prerequisite Skill: Grade 8 Mathematics, Strand: Number, SO 14]**
   - investigate and analyze one-dimensional motion and work done on an object or system, using algebraic techniques *(e.g., the relationships among distance, time and speed; determining area under line in a force–distance graph)* **[Prerequisite Skills: Grade 7 Mathematics, Strand: Patterns and Relations, SOs 2 to 6 and Grade 8 Mathematics, Strand: Patterns and Relations, SOs 2 and 3]**
   - describe how the first and second law of thermodynamics have changed our understanding of energy conversions *(e.g., why heat engines are not 100% efficient)*

3. Apply principles of energy conservation and thermodynamics in investigating, describing and predicting efficiency of energy transformation in technological systems
   - describe qualitatively, and in terms of thermodynamic laws, the energy transformations occurring in devices and systems *(e.g., automobiles, bicycles coming to a stop, thermal power plant, food chain, refrigerator, heat pump)*
   - define, operationally, "useful" energy from a technological perspective, and analyze the stages of "useful" energy transformations in technological systems *(e.g., hydroelectric dam)*
   - explain efficiency as a measure of the useful work compared to the total energy put into an energy conversion process or device
   - apply concepts related to efficiency of thermal energy conversion to analyze the design of a thermal device *(e.g., heat pump, high efficiency furnace, automobile engine, in order to maximize overall efficiency and minimize ecological damage)*
   - compare the energy content of fuels used in thermal power plants in Alberta, in terms of costs, benefits, efficiency and sustainability
   - explain the need for efficient energy conversions in protecting our environment and making judicious use of natural resources *(e.g., co-generation of electricity and heat)*

Skill Outcomes *(focus on problem solving)*

Initiating and Planning

Students will:

Ask questions about observed relationships, and plan investigations of questions, ideas, problems and issues

- design an experiment, identifying and controlling major variables *(e.g., design an experiment to demonstrate the conversion of chemical potential energy to thermal energy, involving a combustion reaction; this example is also applicable to Unit 1)*
- identify the theoretical basis of an investigation, and develop a prediction and a hypothesis that are consistent with the theoretical basis *(e.g., predict or hypothesize the conversion of energy from potential form to a kinetic form, in an experiment using a pendulum or free fall)*
- formulate operational definitions of major variables

Performing and Recording

Students will:

Conduct investigations into relationships between and among observable variables, and use a broad range of tools and techniques to gather and record data and information

- carry out procedures, controlling the major variables and adapting or extending procedures where required *(e.g., perform an experiment to demonstrate the equivalency of work done on an object, and resulting kinetic energy; design a device that converts mechanical energy into thermal energy)*
- compile and organize data, using appropriate formats and data treatments to facilitate interpretation of the data *(e.g., organize data from an experiment to demonstrate the equivalency of work done on an object, and resulting kinetic energy)* **[Prerequisite Skill: Grade 9 Mathematics, Strand: Statistics and Probability, SO 1]**
- use library and electronic research tools to collect information on a given topic *(e.g., compile information on energy content of fuels used in Alberta power plants; trace the flow of energy from the Sun to the lighting system in the school, identifying what changes are taking place at each stage of the process)*
- select and integrate information from various print and electronic sources or from several parts of the same source *(e.g., create multiple-linked documents on the role of alternative energy sources to generate energy in Alberta)*

Analyzing and Interpreting

Students will:

Analyze data and apply mathematical and conceptual models to develop and assess possible solutions

- compile and display evidence and information, by hand or computer, in a variety of formats, including diagrams, flow charts, tables, graphs and scatterplots *(e.g., plot distance–time and force–distance graphs; manipulate and present data through the selection of appropriate tools, such as scientific instrumentation, calculators, databases or spreadsheets)* **[Prerequisite Skills: Grade 9 Mathematics, Strand: Statistics and Probability, SOs 1 to 5, Applied Mathematics 10, SOs A2–2 to A2–4, and Pure Mathematics 10, SOs C2–6 and C2–7]**
- identify limitations of data or measurement *(e.g., measure of local value of gravity varies globally, $9.80 m/s^2 \pm 0.03 m/s^2$)*
- interpret patterns and trends in data, and infer or calculate linear and nonlinear relationships among variables *(e.g., interpret a graph of changing kinetic and potential energy from a*

pendulum during one-half period of oscillation; calculate slope of the line in a distance–time graph; calculate area under the line in a force–distance graph) **[Prerequisite Skills: Grade 7 Mathematics, Strand: Patterns and Relations, SOs 2 to 6, and Grade 8 Mathematics, Strand: Patterns and Relations, SOs 2 and 3]**

- compare theoretical and empirical values and account for discrepancies *(e.g., measure the efficiency of thermal energy conversion systems)* **[Prerequisite Skill: Grade 7 Mathematics, Strand: Number, SO 18]**
- provide a statement that addresses the problem or answers the question investigated, in light of the link between data and the conclusion *(e.g., explain the discrepancy between theoretical and actual efficiency of a thermal energy conversion system)*
- construct and test a prototype of a device or system, and troubleshoot problems as they arise *(e.g., design and build an energy conversion device)*
- propose alternative solutions to a given practical problem, identify the potential strengths and weaknesses of each, and select one as the basis for a plan *(e.g., assess whether coal or natural gas should be used to fuel thermal power plants in Alberta)*
- evaluate a personally designed and constructed device on the basis of criteria they have developed themselves *(e.g., evaluate an energy conversion device)*

Communication and Teamwork

Students will:

Work as members of a team in addressing problems, and apply the skills and conventions of science in communicating information and ideas and in assessing results

- select and use appropriate numeric, symbolic, graphical and linguistic modes of representation to communicate ideas, plans and results *(e.g., use appropriate SI notation, fundamental and derived units; use advanced menu features within a word processor to accomplish a task, to insert tables, graphs, text and graphics)* **[first example Prerequisite Skill: Grade 8 Mathematics, Strand: Number, SO 14]**
- work cooperatively with team members to develop and carry out a plan and troubleshoot problems as they arise *(e.g., develop a plan to build an energy conversion device, seek feedback, test and review the plan, make revisions, and implement the plan)*

Attitude Outcomes

Appreciation of Science

Students will be encouraged to:

- value the role and contribution of science and technology in our understanding of phenomena that are directly observable and those that are not (*e.g., recognize the usefulness of being skilled at mathematics and problem solving; appreciate how scientific problem solving and the development of new technologies are related)*

Interest in Science

Students will be encouraged to:

- show a continuing and more informed curiosity and interest in science and science-related issues *(e.g., demonstrate interest in science and technology topics not directly related to their formal studies)*
- consider further studies and careers in science- and technology-related fields *(e.g., explore where further science- and technology-related studies can be pursued)*

Scientific Attitudes

Students will be encouraged to:

- value the processes for drawing conclusions *(e.g., critically assess their opinion of the value of science and its applications)*

Collaboration

Students will be encouraged to:

- work collaboratively in planning and carrying out investigations, as well as in generating and evaluating ideas *(e.g., willingly work with any classmate or group of individuals, regardless of their age, gender, or physical and cultural characteristics; assume a variety of roles within a group, as required; accept responsibility for any task that helps the group complete an activity)*

Stewardship and Ethical Behaviour

Students will be encouraged to:

- have a sense of personal and shared responsibility for maintaining a sustainable environment *(e.g., willingly evaluate the impact of their own choices or the choices scientists make when they carry out an investigation; consider all perspectives when addressing issues, weighing scientific, technological and ecological factors)*

Safety

Students will be encouraged to:

- show concern for safety, and accept the need for rules and regulations *(e.g., consider safety a positive limiting factor in scientific and technological endeavours; keep the work station uncluttered, with only appropriate laboratory materials present)*

Unit C: Flow of Matter in Living Systems *(Nature of Science emphasis)*

Overview: The fundamental unit of life, the cell, is an example of an efficient open system comprised of a cell membrane and organelles that carry out the basic functions of all living organisms. Students will infer that the study of cells and cellular processes has been enhanced by the development of many kinds of microscopes, including the recently developed confocal laser scanning microscope (CLSM). The understanding of life processes at the microscopic level can also be applied to a multicellular organism.

Focussing Questions: How did the cell theory replace the concept of "spontaneous generation" and revolutionize the study of life sciences? What was, and continues to be the role of imaging technology in furthering our understanding of the structure and function of living cells? How do single cells survive as living organisms? How do plants, as an example of a multicellular organism, accomplish the same functions but on a larger scale—using specialized cells and processes?

Key Concepts

The following concepts are developed in this unit and may also be addressed in other units at other grade levels. The intended level and scope of treatment is defined by the learning outcomes below.

- ☆ technology and the emergence of cell theory
- ☆ role of energy in active and passive processes
- ☆ mechanisms for processes of absorption, secretion and excretion at a cellular level
- ☆ cellular structures and functions
- ☆ use of explanatory and visual models in science
- ☆ cell specialization in a multicellular organism; i.e., plants
- ☆ mechanisms of transport, gas exchange and environmental response in a multicellular organism; i.e., plants

STS and Knowledge Outcomes

Students will:

1. Explain the relationship between developments in imaging technology and the current understanding of the cell
   - trace the development of the cell theory: all living things are made up of one or more cells and the products of those cells, cells are functional units of life, all cells come from preexisting cells *(e.g., from Aristotle to Hooke, Pasteur, Brown, and Schwann and Schleiden)*
   - describe how advancements in knowledge of cell structure and function have been enhanced and are increasing as a direct result of developments in microscope technology and staining techniques *(e.g., electron microscope, confocal laser scanning microscope [CLSM])*
   - identify areas of research into the functioning of living systems at the molecular level *(e.g., DNA and gene mapping, transport across cell membranes)*

2. Describe the function of cell organelles and structures in a cell, in terms of life processes; and apply models to explain these processes and their applications
   - describe the cell as a functioning open system that uses processes involved in acquisition of nutrients, waste excretion, and exchange of matter and energy
   - identify the structure and describe, in general terms, the function of the cell membrane, nucleus, lysosome, vacuole, mitochondrion, endoplasmic reticulum, Golgi apparatus, ribosomes, chloroplast and cell wall, where present, of plant and animal cells
   - compare the structure, chemical composition and function of plant and animal cells, and describe the complementary nature of the structure and function of plant and animal cells
   - describe the role of the cell membrane in maintaining equilibrium while exchanging matter

- describe how knowledge about semi-permeable membranes has been applied in industry *(e.g., attachment of HIV drugs to cells and liposomes, diffusion of protein hormones into cells, separation of bacteria from viruses, purification of water, cheese making, treatment of cancer)*
- compare passive transport of matter by diffusion and osmosis with active transport by endocytosis and exocytosis, in terms of concentration gradients, equilibrium, protein carrier molecules and the particle model of matter
- use models to visualize and explain complex processes like diffusion and osmosis, and the role of the cell membrane in these processes *(e.g., particle model of matter and fluid-mosaic model)*
- explain the functioning of technological processes based upon the principles of diffusion and osmosis *(e.g., staining of cells, desalination of sea water, peritoneal or mechanical dialysis)*
- describe cell size and shape as they relate to the concept of surface area to volume ratio and how that ratio limits cell size *(e.g., compare nerve cells and blood cells in animals; plant root hair cells and chloroplast-containing cells on the leaf surface)* **[Prerequisite Skills: Grade 9 Mathematics, Strand: Shape and Space, SOs 5 and 6]**

3. Analyze plants as an example of a multicellular organism with specialized structures at the cellular, tissue and systems level
   - infer how organism size necessitates the move to a multicellular level of organization and is related to the specialization of plant cells, tissues and systems
   - describe how the cells of the leaf system have a variety of specialized structures and functions; i.e., epidermis including guard cells, palisade tissue cells, spongy tissue cells, and phloem and xylem vascular tissue cells
   - explain and investigate the transport system in plants; i.e., xylem and phloem tissues and the processes of transpiration, including the cohesion and adhesion properties of water, turgor pressure and osmosis; diffusion; active transport; and root pressure in root hairs
   - explain and investigate the gas exchange system in plants; i.e., lenticels, guard cells and stomata, and the process of diffusion
   - explain and investigate phototropism and geotropism as examples of control systems in plants
   - trace the development of theories of phototropism and geotropism *(e.g., from Darwin and Boysen-Jensen to Went)*

Skill Outcomes *(focus on scientific inquiry)*

Initiating and Planning

Students will:

Ask questions about observed relationships, and plan investigations of questions, ideas, problems and issues

- identify questions to investigate that arise from practical problems and issues *(e.g., how do plants arrange root systems to accommodate different environmental conditions; how do plants react to varying levels of such things as light, fertilizer)*
- define and delimit problems to facilitate investigation *(e.g., rate of water loss)*
- design an experiment, identifying and controlling major variables *(e.g., design an investigation on nutrient acquisition at the cellular level)*
- state a prediction and a hypothesis based on available evidence and background information *(e.g., hypothesize how biochemical interconversions of starch and glucose might regulate the turgor pressure of cells)*

- identify the theoretical basis of an investigation, and develop a prediction and a hypothesis that are consistent with the theoretical basis *(e.g., predict the different action of a sucrose solution and a starch solution when placed in water, and infer why the solutions behave differently)*
- formulate operational definitions of major variables *(e.g., define concentration gradient, equilibrium)*

Performing and Recording

Students will:

Conduct investigations into relationships between and among observable variables, and use a broad range of tools and techniques to gather and record data and information

- carry out procedures, controlling the major variables and adapting or extending procedures where required *(e.g., perform an experiment to demonstrate the phenomena of plasmolysis and deplasmolysis in plant cells, such as staminal hairs or aquatic leaf cells, and describe the observed events in terms of the tonicity of the cells and solutions)*
- use instruments effectively and accurately for collecting data *(e.g., use a microscope to observe movement of water in plants; prepare wet mounts of tissue from flowering plants, and observe cellular structures specific to plant and animal cells; stain cells to make them visible)*
- estimate quantities *(e.g., compare sizes of various types of cells; calculate magnification, field of view and scale)* **[Prerequisite Skills: Grade 8 Mathematics, Strand: Number, SO 12 and Strand: Shape and Space, SO 11]**
- compile and organize data, using appropriate formats and data treatments to facilitate interpretation of the data *(e.g., calculate the size of a cell from knowledge of microscope magnification power and field of view)* **[Prerequisite Skill: Grade 8 Mathematics, Strand: Number, SO 12]**
- use library and electronic research tools to collect information on a given topic *(e.g., upload and download text, image, audio and video files on emerging technologies to study cells)*
- select and integrate information from various print and electronic sources or from several parts of the same source *(e.g., create multiple-linked documents or summarize articles based on the scientific principles and/or technological developments)*

Analyzing and Interpreting

Students will:

Analyze data and apply mathematical and conceptual models to develop and assess possible solutions

- compile and display, by hand or computer, evidence and information in a variety of formats, including diagrams, flow charts, tables, graphs and scatterplots *(e.g., calculate and graph the surface area to volume ratios of a variety of model cell sizes and shapes, when one variable is changed at a time)* **[Prerequisite Skills: Grade 9 Mathematics, Strand: Shape and Space, SOs 5 and 6]**
- interpret patterns and trends in data, and infer or calculate linear and nonlinear relationships among variables *(e.g., compare the surface area to volume ratio of various cells, and relate the findings to the cell's function)* **[Prerequisite Skills: Grade 9 Mathematics, Strand: Shape and Space, SOs 5 and 6]**
- provide a statement that addresses the problem or answers the question investigated, in light of the link between data and the conclusion *(e.g., observe and record macroscopic and microscopic changes in a growing plant for evidence of differentiation)*
- explain how data support or refute the hypothesis

- construct and test a prototype of a device or system, and troubleshoot problems as they arise *(e.g., create a model of a cell to perform a certain function, such as using a balloon with tape on it to represent a guard cell)*
- identify new questions or problems that arise from what was learned *(e.g., determine the purpose of cellular structures observed in living and prepared materials by use of dissecting and compound microscopes, or micrographs)*

Communication and Teamwork

Students will:

Work as members of a team in addressing problems, and apply the skills and conventions of science in communicating information and ideas and in assessing results

- communicate questions, ideas and intentions; and receive, interpret, understand, support and respond to the ideas of others *(e.g., describe the appearance of cytoplasmic streaming in a cell, and communicate the inference about similar movement in most cells of a multicellular organism)*
- select and use appropriate numeric, symbolic, graphical and linguistic modes of representation to communicate ideas, plans and results *(e.g., draw analogies between the evidence for division of labour within cells to services in communities; record and explain the movement of water in plants)*

Attitude Outcomes

Appreciation of Science

Students will be encouraged to:

- value the role and contribution of science and technology in our understanding of phenomena that are directly observable and those that are not *(e.g., appreciate how scientific problem solving and the development of new technologies are related; recognize the contribution of science and technology to the progress of civilizations)*

Interest in Science

Students will be encouraged to:

- consider further studies and careers in science- and technology-related fields *(e.g., investigate careers in fields such as botany, forestry, horticulture, cytology, genetics, laboratory technology, nephrology and public health)*

Scientific Attitudes

Students will be encouraged to:

- use factual information and rational explanations when analyzing and evaluating *(e.g., seek new models, explanations and theories when confronted with discrepant events)*

Collaboration

Students will be encouraged to:

- work collaboratively in planning and carrying out investigations, as well as in generating and evaluating ideas *(e.g., assume a variety of roles within a group, as required; evaluate the ideas of others objectively; accept responsibility for any task that helps the group complete an activity)*

Stewardship and Ethical Behaviour

Students will be encouraged to:

- want to take action for maintaining a sustainable environment *(e.g., willingly evaluate the impact of their own choices or the choices scientists make when they carry out an investigation)*

Safety

Students will be encouraged to:

- show concern for safety, and accept the need for rules and regulations *(e.g., treat equipment with respect, and carefully manipulate materials)*
- be aware of the direct and indirect consequences of their actions *(e.g., assume responsibility for the safety of all those who share a common working environment, by cleaning up after an activity and disposing of materials in a safe place)*

Unit D: Energy Flow in Global Systems *(Social and Environmental Contexts emphasis)*

Overview: Solar energy sustains life and drives weather systems on Earth. Without solar energy there would be no heat or precipitation and, therefore, no natural vegetation or life on Earth. Students will gain an understanding that the transfer of thermal energy by radiation, convection and conduction at and near Earth's surface results in a variety of climate zones with characteristic weather patterns and biomes. Climatic factors determine the flora and fauna found in each of the world's major biomes. Recent developments in satellite imaging technology help us analyze the interrelationships among human activity, climate change and the sustainability of biomes.

Focussing Questions: Are there relationships between solar energy, global energy transfer processes, climate and biomes? What evidence suggests our climate may be changing more rapidly than living species can adapt? Is human activity the cause for rapid climate change, and in meeting human needs, how can we reduce our impact on the biosphere and on global climate?

Key Concepts

The following concepts are developed in this unit and may also be addressed in other units at other grade levels. The intended level and scope of treatment is defined by the learning outcomes below.

- ☆ interrelationship among species, biomes and climate
- ☆ radiation and convection
- ☆ greenhouse effect and global warming
- ☆ closed, open, isolated systems
- ☆ atmosphere, hydrosphere, cryosphere, biosphere
- ☆ water cycling and phase change
- ☆ climatic variability, change and modification
- ☆ models of climate—atmospheric models, ocean models, integrated assessment models
- ☆ interrelationship of technology, science, society and environment for sustainability

STS and Knowledge Outcomes

Students will:

1. Explain how climate profoundly affects the lives of people and other species in many ways, and explain the societal need to investigate climatic change
   - describe, in general terms, the responses of human and other species to extreme climatic conditions *(e.g., housing design and animal shelter, clothing and fur in conditions of extreme heat, cold, dryness/humidity, wind)*
   - describe the role of science in furthering the understanding of climate and climate change through international programs *(e.g., World Meteorological Organization: World Weather Watch, World Climate and Global Atmosphere Watch, Project SHEBA)*
   - describe the role of technology in furthering the understanding of climate and climate change *(e.g., computer models, measurements of greenhouse gases, satellite imaging technology)*
   - describe how rapid climatic change will result in population shifts and economic turmoil *(e.g., The Intergovernmental Panel on Climate Change (IPCC); the study of paleoclimates to test models is being used to make policy decisions for future climate scenarios)*

2. Analyze the relationships among net solar energy, global energy transfer processes—primarily radiation, convection and hydrologic cycle—and climate
   - describe, in general terms, the relationships among solar energy reaching Earth's surface and time of year, angle of inclination, length of daylight, cloud cover, albedo effect and dust particle distribution

- analyze, in general terms, the net radiation budget, using per cent; i.e., solar energy input, terrestrial energy output, net radiant energy **[Prerequisite Skill: Grade 8 Mathematics, Strand: Number, SO 13]**
- describe, in general terms, how thermal energy is transferred through the atmosphere; i.e., global wind patterns, Coriolis effect, weather systems, and through the hydrosphere; i.e., ocean currents, large bodies of water, from latitudes of net radiation surplus to latitudes of net radiation deficit *(e.g., analyze static and animated satellite images)*
- explain how thermal energy transfer through the atmosphere and hydrosphere affect climate
- describe and explain how the processes of evaporation, condensation and precipitation transfer thermal energy through the hydrologic cycle; i.e., use of simple calculations of heat of fusion (melting at 0°C) and vaporization (boiling at 100°C), and $Q=mc\Delta t$ to convey amounts of thermal energy involved in these processes **[Prerequisite Skills: Grade 8 Mathematics, Strand: Patterns and Relations, SOs 4 to 6]**

3. Analyze the relationships among input solar energy, output terrestrial energy, energy flow within the biosphere and the characteristics of biomes
   - indicate that the biosphere includes the three major components of Earth—the atmosphere, the hydrosphere and the lithosphere
   - explain why a biome is an open system in terms of its components, such as input and output of energy and matter and changes in its boundaries
   - compare and contrast cells and biomes as open systems
   - relate and analyze the characteristics of climagrams of two major biomes; i.e., grasslands, desert, tundra, taiga, deciduous and rain forest, to net radiant energy and climatic factors; i.e., temperature, moisture, sunlight and wind, and explain why biomes with similar characteristics can exist in different geographical locations

4. Analyze the impact of change in global energy transfer systems on humans and the biosphere
   - analyze the impact of human actions on energy transfer in biomes and their potential impact on climate *(e.g., species depletion, habitat reclamation/destruction, greenhouse gases, draining of wetlands, forest fires, deforestation)*
   - describe the limitations of scientific knowledge and technology in making predictions related to climate and weather *(e.g., the direct and indirect impacts on Canada's agriculture, forestry and oceans resulting from climate change, or resulting from changes in energy transfer systems, such as ocean currents and global wind patterns)*
   - describe and analyze the evidence for and against rapid climatic change brought on by human activity *(e.g., global warming, deforestation, water use and diversion)*
   - assess, from a variety of perspectives, the risks and benefits of human activity and its impact on the biosphere and the climate *(e.g., Gaia hypothesis, native beliefs, economic perspectives)*

Skill Outcomes *(focus on applying science to inform decision-making processes)*

Initiating and Planning

Students will:

Ask questions about observed relationships, and plan investigations of questions, ideas, problems and issues

- identify questions to investigate that arise from practical problems and issues *(e.g., develop questions related to global warming, such as "What will be the impact of global warming on Canada's northern biomes?")*

- identify the theoretical basis of an investigation, and develop a prediction and a hypothesis that are consistent with the theoretical basis *(e.g., relate greenhouse effect and global warming)*
- design an experiment, and identify specific variables *(e.g., investigate the heating effect of solar energy)*
- formulate operational definitions of major variables *(e.g., define heat of fusion or vaporization as amount of energy to change state of matter at melting or boiling points)*

Performing and Recording

Students will:

Conduct investigations into relationships between and among observable variables, and use a broad range of tools and techniques to gather and record data and information

- carry out procedures, controlling the major variables and adapting or extending procedures where required *(e.g., perform an experiment to determine the ability of various materials to absorb or reflect solar energy)*
- use instruments effectively and accurately for collecting data *(e.g., use a barometer, rain gauge, thermometer)*
- compile and organize data, using appropriate formats and data treatments to facilitate interpretation of the data *(e.g., organize data to prepare climagrams for comparing biomes)*
- use library and electronic research tools to collect information on a given topic *(e.g., research sources of greenhouse gases; research protocols to control human sources of greenhouse gases)*
- select and integrate information from various print and electronic sources or from several parts of the same source *(e.g., collect weather data, both historic and current, from the Internet)*

Analyzing and Interpreting

Students will:

Analyze data and apply mathematical and conceptual models to develop and assess possible solutions

- describe and apply classification systems and nomenclatures used in the sciences *(e.g., classify biomes)*
- compile and display, by hand or computer, evidence and information in a variety of formats, including diagrams, flow charts, tables, graphs and scatterplots *(e.g., construct climate graphs of two of: grasslands, deserts, tundra, taiga, deciduous and rain forests)*
- identify and apply criteria, including the presence of bias, for evaluating evidence and sources of information *(e.g., investigate the issue of global climate change)*
- interpret patterns and trends in data, and infer or calculate linear and nonlinear relationships among variables *(e.g., analyze a graph of mean monthly temperatures for cities of similar latitudes but different climate)*
- apply and assess alternative theoretical models for interpreting knowledge in a given field *(e.g., assess models for global warming)*
- identify limitations of data, evidence or measurement *(e.g., list the limitations of data and evidence for past changes to climate)*
- provide a statement that addresses the problem or answers the question investigated, in light of the link between data and the conclusion *(e.g., summarize an analysis of the relationship between human activity and changing biomes)*
- explain how data support or refute the hypothesis or prediction *(e.g., provide evidence for or against human activity being responsible for climate change)*

- propose alternative solutions to a given practical problem, identify the potential strengths and weaknesses of each, and select one as the basis for a plan *(e.g., design a home for a specific climate)*

Communication and Teamwork

Students will:

Work as members of a team in addressing problems, and apply the skills and conventions of science in communicating information and ideas and in assessing results

- select and use appropriate numeric, symbolic, graphical and linguistic modes of representation to communicate ideas, plans and results *(e.g., use appropriate SI notation, fundamental and derived units)* **[Prerequisite Skill: Grade 8 Mathematics, Strand: Number, SO 14]**
- synthesize information from multiple sources or from complex and lengthy texts, and make inferences based on this information *(e.g., use integrated software effectively and efficiently to reproduce work that incorporates data, graphics and text)*
- identify multiple perspectives that influence a science-related decision or issue *(e.g., consult a wide variety of electronic sources that reflect varied viewpoints and economic, social and scientific perspectives on global warming)*
- develop, present and defend a position or course of action, based on findings *(e.g., use past and current findings on climate to support a position on future climate patterns)*

Attitude Outcomes

Appreciation of Science

Students will be encouraged to:

- value the role and contribution of science and technology in our understanding of phenomena that are directly observable and those that are not *(e.g., recognize the usefulness of static and moving satellite imagery to investigate climate; recognize the contributions to the study of climate over time, and in predicting weather phenomena)*
- appreciate that the applications of science and technology can raise ethical dilemmas *(e.g., recognize that human actions may affect the sustainability of biomes for future generations)*

Interest in Science

Students will be encouraged to:

- show a continuing and more informed curiosity and interest in science and science-related issues *(e.g., express interest in science and technology topics not directly related to their formal studies)*

Scientific Attitudes

Students will be encouraged to:

- evaluate evidence confidently, and consider alternative perspectives, ideas and explanations *(e.g., collect evidence, ask questions, do research)*
- use factual information and rational explanations when analyzing and evaluating *(e.g., critically evaluate inferences and conclusions, free of bias, being cognizant of the many variables involved in experimentation)*
- value the processes for drawing conclusions *(e.g., critically assess their opinion of the value of science and its applications)*

Collaboration

Students will be encouraged to:

- work collaboratively in planning and carrying out investigations, as well as in generating and evaluating ideas *(e.g., assume a variety of roles within a group, as required; accept responsibility for any task that helps the group complete an activity; seek the point of view of others, and consider a multitude of perspectives)*

Stewardship and Ethical Behaviour

Students will be encouraged to:

- have a sense of personal and shared responsibility for maintaining a sustainable environment *(e.g., participate in civic activities related to the preservation and judicious use of the environment and its resources; consider all perspectives when addressing issues, weighing scientific, technological and ecological factors; remain critical-minded regarding the short- and long-term consequences of sustainability)*
- project the personal, social and environmental consequences of proposed action *(e.g., consider all perspectives when addressing issues, weighing scientific, technological and ecological factors)*
- want to take action for maintaining a sustainable environment *(e.g., encourage their peers or members of their community to participate in a project related to sustainability; participate in the social and political systems that influence environmental policy in their community)*

Safety

Students will be encouraged to:

- be aware of the direct and indirect consequences of their actions